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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

HYDROCYANIC-ACID GAS AGAINST HOUSEHOLD INSECTS.[1]

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INTRODUCTION.

The purpose of this bulletin is to enable the reader to use hydrocyanic-acid gas safely and effectively as a means of destroying the various insect pests of the household, such as bedbugs, fleas, cockroaches, ants, clothes moths, and carpet beetles.

By way of caution it should be stated at the outset that hydrocyanic-acid gas is extremely poisonous and is fatal to human beings if breathed in any quantity, while the chemicals used in generating the gas—sodium cyanid or potassium cyanid and sulphuric acid—are also very poisonous, the cyanid being necessarily fatal if only a small piece be eaten and the sulphuric acid burning badly when coming in contact with the skin. Special attention is called to the full discussion of this subject on pages 6 to 8, under the heading "The cyanid and gas a deadly poison." *The chemicals must be handled with the greatest care and the fumigation process must not be undertaken until it is thoroughly understood in every particular.*

Hydrocyanic-acid gas has been for more than 20 years one of the most effective known fumigants in use against noxious insects. It has a wide range of applicability, including the control of scale insects on citrus and nursery stock and the fumigation of greenhouses and cold frames, and it is a standard remedy against insects in mills and warehouses.[2] As a fumigant against household insects it has

[1] A revision of Circular No. 163 of the Bureau of Entomology.

[2] Entomologists have long noticed that insects vary greatly in their susceptibility to cyanid fumes. The ordinary killing bottle used in making collections contains cyanid of potassium, or cyanid of sodium, covered with plaster of Paris, which the fumes of the cyanid penetrate. Certain weevils, especially hard-bodied forms, will frequently be left overnight in a cyanid bottle and recover after being removed. It has been noticed also that in greenhouses certain insects recover after fumigation with hydrocyanic-acid gas.

been in use since 1898 and has proved so uniformly effective for this purpose when properly applied that in spite of its extremely poisonous character it has almost entirely replaced other and less poisonous gases.[1] Rats and mice are also killed by its use, and it fortunately has the effect of first causing these animals to rush out from their holes into the open, so that the subsequent annoyance of dead rats and mice in walls and under floorings is not experienced. The absence of any bleaching or tarnishing tendency when pure materials are used is also a strong point in its favor.

MATERIALS USED IN THE FUMIGATION PROCESS AND THEIR PROPORTIONS.

In the formation of hydrocyanic-acid gas for the purposes of fumigation sulphuric acid in a diluted form is permitted to act on either sodium cyanid or potassium cyanid. In the resulting reaction hydrocyanic-acid gas is liberated, while the remainder of the salt unites with the sulphuric acid to form sodium or potassium sulphate, nonpoisonous compounds. Up to the year 1909 cyanid of potassium was used almost entirely for this purpose, but since that time cyanid of sodium has taken the place of potassium cyanid and the latter is not now easily obtainable.[2] Sodium cyanid in its pure form liberates nearly a third more hydrocyanic-acid gas per pound than does cyanid of potassium and is a satisfactory substitute for potassium cyanid. Its slightly greater cost is balanced by the larger yield of gas. Cyanid of sodium is now being manufactured in special 1-ounce molds for fumigation purposes.

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[1] Carbon bisulphid has sometimes been recommended as a substitute for hydrocyanic-acid gas. The extreme inflammability of this substance, however, and the explosiveness of its vapor when confined render it perhaps less available, and the danger in its use more than counteracts the danger to human beings from hydrocyanic-acid gas. It has been found, moreover, that hydrocyanic-acid gas is much more effective for the control of all groups of household insects, with the exception of the beetles, than is the other fumigant.

[2] Should potassium cyanid be obtainable, and used in the fumigation, 1 fluid ounce of commercial sulphuric acid (about 1.84 sp. gr., or 66° Baumé) diluted with 3 fluid ounces of water (to increase the bulk of the liquid and insure complete chemical action) and 1 ounce of high-grade (98 per cent) cyanid of potassium must be used for every 100 cubic feet of space. The formula per hundred cubic feet, therefore, is as follows:

Potassium cyanid (98 per cent)	avoirdupois ounce	1
Commercial sulphuric acid	fluid ounce	1
Water	fluid ounces	3

Potassium cyanid was formerly obtainable in various technical grades, ranging between 40 per cent and 98 to 100 per cent actual cyanid, the remainder being an inert salt, usually sodium carbonate or sodium chlorid, which is of no value in fumigation and in the case of sodium chlorid is a positive detriment, as this substance, acted upon by sulphuric acid, produces hydrochloric acid, which decomposes the hydrocyanic-acid gas. In cases of extreme adulteration as much as 60 per cent of the fumigant may be decomposed in this manner, resulting in inferior effectiveness and tending to tarnish polished metal surfaces exposed to the gas. If chemically pure cyanid is used little tarnishing results.

In the use of sodium cyanid the grade known as "98 to 99 per cent"[1] should be procured, and combined with the other materials according to the following formula:[2]

Sodium cyanid	avoirdupois ounce	1
Sulphuric acid	fluid ounces	1½
Water	do	3

In this combination sufficient sulphuric acid is added to liberate completely the excess hydrocyanic acid in the sodium cyanid, since in the use of this chemical a greater amount of sulphuric acid is necessary for the complete exhaustion of the cyanid.

For loosely constructed frame houses the foregoing amounts may be doubled for each 100 cubic feet. The cyanid costs from 25 to 50 cents a pound, and the sulphuric acid (thick or more sirupy commercial brand) about 4 cents a pound.

The purity of the cyanid and sulphuric acid to the degree indicated is essential to the success of the fumigation.

Druggists and other retail dealers generally have in stock only impure grades of sodium cyanid, used for other technical purposes but unsuitable for fumigation on account of the greater or less percentage of sodium chlorid (common salt) and other adulterants contained. The presence of salt, as noted in relation to potassium cyanid (see footnote[2], p. 2), greatly reduces the amount of hydrocyanic-acid gas given off, and it is therefore highly important to insist on the best commercial grade of sodium cyanid, known as 98–99 per cent, containing 51 per cent cyanogen, such as is manufactured especially for fumigation purposes. The greater amount of cyanogen (available hydrocyanic-acid gas) in cyanid of sodium necessitates the use of a correspondingly greater amount of acid, as indicated in the formula for sodium cyanid.

DIRECTIONS FOR FUMIGATION.

Before beginning the fumigation the house must be vacated. It is not necessary to remove any of the furniture or household belongings unless of polished nickel or brass, which may tarnish a little. Liquid or moist foods, as milk, meats, or other larder supplies that are not dry and might absorb the gas, should be removed from the house. All fires should be put out; for while the gas will not burn at the dilution employed in fumigation, it is as well to take no risks.

The cubic contents of each room on each floor should be carefully computed and a tabular statement prepared, such as the one given

[1] This grade was formerly known as 128–130 per cent cyanid, since an equal amount by weight of chemically pure sodium cyanid liberates 33 per cent more hydrocyanic-acid gas than does pure potassium cyanid, and this was expressed by designating the pure sodium cyanid as 133 per cent.

[2] For rapid work it may be stated that in either of the foregoing formulas, where the cyanid is weighed out in pounds avoirdupois, the same proportions may be used as expressed in the formulas, the acid and water being measured in pints.

below, designating for each floor and the different rooms the capacity and the amount of water, acid, and cyanid needed.

Table designating rooms, capacity, and amounts of chemicals.

Floor.	Room.	Cubic feet.	Water.	Acid.	Cyanid.
			Fl. oz.	*Fl. oz.*	*Avd. oz.*
Fourth	Garret	17,000	210	70	70
Third	Front	2,800	84	28	28
	Middle	1,400	42	14	14
	Back	2,200	66	22	22
Second	Front	15,500	165	55	55
	Middle	2,200	66	22	22
	Back	2,000	60	20	20
First	Parlor	14,400	132	44	44
	Middle	2,400	72	24	24
	Dining	2,900	87	29	29
Basement	Servant's	1,200	36	12	12
	Hall	2,000	60	20	20
	Kitchen	1,800	54	18	18
Total		37,800	1,138	378	378

The house is prepared for treatment by seeing that all the windows are closed and calked, if of loose construction, with wet paper or cotton batting tucked tightly into the crevices. Gummed paper strips are obtainable for this purpose and may be pasted over the crevices in the doors and windows, making the room practically gas-tight. As the building must be aired by opening the windows from the outside, those selected to be opened should be examined to see that they pull down easily, and if too high to be reached from the ground should be provided with strong cords reaching to the ground that they may be easily opened from below. They should be opened before closing for the last time in order to test the strength of the cord and should not be pasted up or calked. The fireplace flues in the different rooms should be stuffed with paper and the registers closed. Carpets and rugs should be cleared away from the floor as far as possible to prevent their being burned should the acid spatter or boil over.

For generators, stoneware or crockery jars having a capacity of 4 gallons are preferable and may be used with a charge of up to 8 pounds of cyanid. One of these vessels should be placed in each room, with the exception of large rooms requiring a charge of more than 3 pounds of cyanid, when the charge may be divided. One vessel will suffice for each 3,000 or 4,000 cubic feet, preferably the former amount. Under each of these vessels a larger vessel or a rather thick carpeting of old newspapers should be placed, and care must be exercised to see that none of the vessels is cracked, on account of the danger of breakage from the heat generated by the process. Deep vessels are more satisfactory for the experiment than the washbasins often used, but the latter are always available and will serve the purpose. Deeper vessels give greater depth to the

water and acid and accelerate the chemical action, and there is less danger of spattering. Whenever the room is of such size that much more than 3 pounds of cyanid must be employed for it, it is perhaps better to make two charges of half size for such room.

PROCESS OF FUMIGATION.

In the process of generating the gas the water may be measured in a glass beaker indicating ounces, or, for convenience, in a pint cup, and poured into the generators. The acid, measured in the same receptacle, is then slowly and gently poured into the water to avoid splashing or boiling. For all ordinary purposes 1½ pints of the acid and 3 pints of water are sufficient for each pound of sodium cyanid. *The acid should never be placed in the generators first, as advised by some writers, since experience shows that this is dangerous, spattering being almost certain to follow.* When the acid is poured into the water in the jar an ebullition of vapor sometimes arises. Considerable heat is also developed by the addition of the acid.

When the cyanid, which previously should be broken into pieces the size of an egg, is finally dropped into the combined acid and water mixture bubbling takes place similar to that produced by a red-hot iron dipped into cold water. The generation of hydrocyanic-acid gas, the most poisonous gas in common use, begins at once. The gas is colorless and has an odor which has been likened to that of peach kernels. This odor is decidedly metallic, like that produced by striking two pieces of metal together, or of metal against stone. If the fumes are inhaled in any considerable quantity they are almost certain to prove fatal; hence the necessity of extreme care and the advisability of the presence of two intelligent operators in this work. It is even advisable, especially when the first fumigation is undertaken, that one who has had experience with this method of fumigation be present to give directions.

The measuring and preparation of the water and acid in the fumigating jars should be undertaken in a room with a tile or concrete floor if possible, as the strong acid used is apt to injure wooden floors or carpets should spilling occur. The jars may then be distributed to the different rooms and a bag containing the requisite cyanid placed by the side of each.

The house is now in readiness to be fumigated. Coats and hats and everything needed outside must be removed, and preferably two persons should then go to the top of the house, taking different rooms on the same floor to expedite the process, and place the bags containing the cyanid gently into the vessels to receive them. The chemical action will begin at once, but the gas will not rise to any extent for a few seconds or a quarter of a minute, and there is ample time to leave the room quickly without danger of breathing the gas. Having

finished the garret or top floor, the operators should pass rapidly to the next, and so on to the basement, making their exit through the lower door to the street.

Hydrocyanic-acid gas is lighter than air, and consequently rises; therefore the operation must be begun at the top of the house.

The house should be locked from the outside and, if necessary, a warning sign put up to caution against entrance.

The preparation of the different rooms, getting their cubic contents, placing the vessels, and preparing the charges, in a house of the size indicated in the foregoing table, will take from two to three hours, and this much time must be allowed for. The house should remain closed, for the gas to become fully generated and do its work, for from 4 to 6 hours at least—preferably, however, and to get the greatest efficiency, for 24 hours.

Better results are claimed for a warm temperature, say, 70° F. or above, than in a temperature as low as 50° F. or below. Under 50° most insects become torpid, and the effective action of the chemical will be diminished, especially in very low temperatures.

At the close of the operation the doors may be opened and the windows lowered or opened from the outside, and after an hour's airing the house may be entered, if no strong odor of gas is detected, and opened up even more thoroughly, if possible, to allow a complete airing for several hours. The house should not be reinhabited until all traces of the odor of the gas have disappeared. This odor, as stated before, has been compared to that of peach kernels.

The contents of the generating jars should be poured into the sewer trap, or disposed of in some place where they will not be a source of danger, and the jars thoroughly cleaned.

THE CYANID AND GAS A DEADLY POISON.

In the use of hydrocyanic-acid gas for household fumigation we must not for a single instant lose sight of the fact that we are dealing with one of the most poisonous substances known; that the accidental eating of a small portion of cyanid will necessarily be fatal; and that the inhalation of a few breaths of the gas will asphyxiate, and, if rescue be not prompt, have a fatal termination. It is much better, therefore, if fumigation be contemplated, to put the work in the hands of some one who has had experience, if such a person be available; if not, to consider carefully all the recommendations and precautions in this bulletin and become thoroughly familiarized with them before undertaking the experiment.

While the writers thus strongly emphasize the dangerous and even fatal qualities of this gas when breathed by human beings, it is worthy of remark that in the thousands of operations which have been carried on with this gas in different parts of the world only

three cases of fatal accidents to human beings have been recorded. These were due to extreme carelessness in its use. In one case the operator went back into the house after having dropped the bags and closed the building for some time. The abundant experience which has been gained by the different members of the force of the Bureau of Entomology and many others in the fumigation of dwelling houses has demonstrated that all danger is easily overcome by care in conducting the operation. In all the house-fumigation work which has been done during the last 10 years no accident has occurred, except in one or two instances the burning of rugs in attempting to set off charges in too small vessels and a case of headache where a few whiffs of much diluted gas had been accidentally breathed.

It follows, from what we have just said, that there may be danger from fumigating one house in a row of houses separated only by party walls, the other houses being inhabited. Unnoticed cracks in a wall would admit the poisonous gas to the neighboring house. In such a case a householder must consult his neighbors. In isolated houses, however, with the precautions indicated, the operation will be a safe one. The fact that birds resting on the ridge of houses in which the gas was being liberated have been killed by the ascending fumes indicates also that where the house to be fumigated immediately adjoins a higher structure to which the gas may possibly gain entrance there may be some danger to the occupants of the higher structure.

Single apartments or rooms in buildings should not be fumigated except when the whole building can be vacated during the operation. In case of contiguous houses of loose construction an arrangement should be made so that the adjoining houses also may be vacated during fumigation.[1]

In handling the acid great care should be used in pouring it from the bottle and in putting it into the vessels to avoid spattering on the hands or face, since it will burn rapidly through the skin, and should it spatter into the eyes would cause serious inflammation or loss of sight, or if on the clothing it would burn a hole in the garment. Should a drop fly to the hands or face, bathe the part promptly and freely in water, and the same also for garments or the carpet. It is further desirable to have at hand a bottle of ammonia to neutralize the acid should it spatter on clothing.

The handling of the dry cyanid is not accompanied by any danger if there be no open wound on the hand, but it is advisable to wear an old pair of gloves in breaking up the cyanid and putting it into the

[1] One of the fatalities mentioned in a preceding paragraph resulted from the fumigation of a basement in an apartment house not only without seeing that these apartments and the entire building were vacated and closed during the operation, but without even warning the occupants in the apartments above.

sacks, these gloves to be afterwards burned. The fact that the cyanid has a superficial resemblance to sugar adds to the danger of keeping it about the premises, and it is much better at once to bury deeply or throw down the sewer trap any left-over cyanid.

SUMMARY OF METHOD.

The general directions for treatment may be briefly summarized as follows:

(1) Prepare tabular statement designating room capacity and amount of chemicals for each compartment and secure the chemicals and vessels for generating the gas.

(2) Arrange for the opening of doors and windows from the outside at the conclusion of the fumigation and close all registers, fireplaces, and other openings. Do necessary calking and remove carpets and rugs and moist food material and any metallic objects which are likely to be tarnished.

(3) Place the generating vessels in each room with a thick carpeting of old newspapers under each.

(4) Break up the cyanid out of doors and place it in thin paper sacks containing charges suited to the amounts to be used in the different rooms.

(5) Measure into each of the generating jars the proper amount of water and afterwards add the acid slowly in the proper amount to each of the jars.

(6) Take the cyanid in bags in a basket and place the bags containing the proper amount alongside of the generating jars in each room.

(7) Start at the top of the house and place the cyanid gently, so as not to spatter, into each jar and quickly leave the room. As soon as the upper floor is finished go to the next lower, and pass in this manner from floor to floor until the basement is reached and exit is made through the lower door. If two persons work together in this operation they should both be on the same floor together, taking different rooms.

(8) The following day, or after the completion of the fumigation, open the windows and doors from the outside and let the house ventilate for an hour before entering it.

(9) After the house is thoroughly ventilated and the odor of the gas has disappeared, empty the jars in a safe place, preferably through the sewer trap, and wash them thoroughly and repeatedly before using them for any household purpose.

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